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Development and integration of an electrochemical system in a LOC device for DNA detection

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Abstract

In this work we have developed an electrochemical detection system (EDS), with the aim to simplify and reduce the cost of a Lab on a Chip (LOC) device [1] in the case of qualitative DNA detection measurements. For that, in addition to the optical detection system of the LOC device an EDS is added.

The LOC system consists of a potable platform reader-actuator and a disposable labcard capable of performing nucleic acid concentration and amplification. The sample is injected in the labcard and, after the elution of the DNA, it is transferred to the PCR chamber, where the DNA is amplified and transferred to the detection chamber. In this chamber an electrochemical sensor is integrated.

In addition, a potentiostat/galvanostat which is integrated in the LOC system is developed for the electrochemical measurements.

Keywords: LOC; Electrochemical Detection System; DNA.

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1. Introduction

LOC devices have achieved a wide popularity as they have opened the possibilities of portable analysis in contrast to complex laboratory assays. The addition of an electrochemical detection system to a LOC device can provide significant advantages. Electrochemistry detection can provide high sensitivity in addition to low cost, fast response and small dimensions which are key factors for a portable device.

To fulfill these requirements, the main objective of this work is to develop a low cost system with integrated electrodes and electronics [2], which improves the signal to noise ratio of the electrochemical sensor.

2. Device description and experiments

The electrochemical sensors are integrated in the electrochemical detection chamber of the labcard. For that, gold and platinum electrodes are deposited by sputtering on COC (cycloolefin copolymer) achieving a total integration of the electrodes in the microfluidic cartridge, as it is shown in Fig 1.

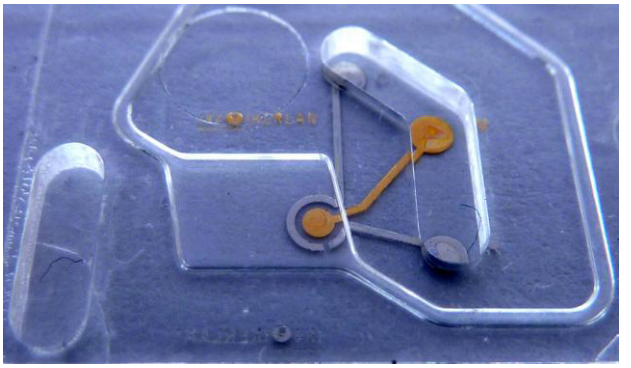


Fig 1. Electrochemical sensor, with sputtered gold working electrode and sputtered platinum counter and reference electrodes integrated in the microfluidic cartridge.

In Fig 2, the block diagram of the fabricated electrochemical module is shown. This module consists of three main parts: impedance matching, current measurement and error signal amplification,

Across the impedance matching module, input impedance higher than 82GΩ is achieved by making a guarding of the input signal, that will therefore decrease the error
with respect to the applied reference voltage.

The current measurement module allows to perform a configuration with single or double power supply mode. If the currents that are going to be measured in the application are higher than 100nA, the single power supply mode is used for cost reduction.

The performed system has a high input impedance and is able to measure with a resolution better than 8nA in the ±1μA current range.

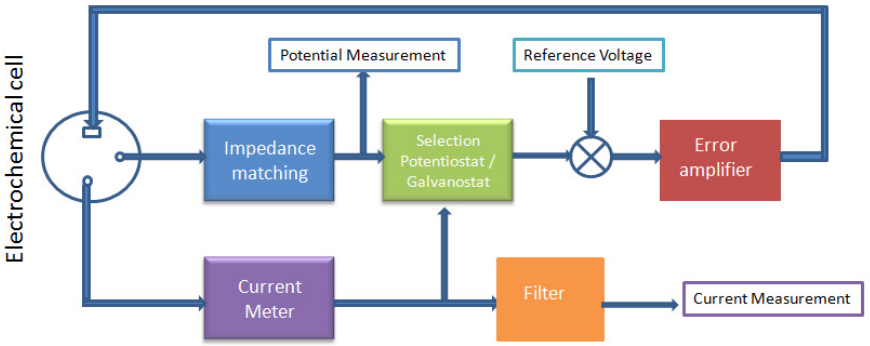


Fig 2. Potentiostat/Galvanostat design. Block diagram.

Since the microfluidic cartridge exhibits a high degree of integration, the read-out and the processing unit for the system have to combine the circuitry necessary for the cartridge control and the hardware which is required for the particular sensor. Therefore, in order to integrate all the electronics of the system, the control electronics of the processing unit of the LOC is used for the cartridge control and also for the hardware which is required for the electrochemical sensor. The fabricated electronic card is shown in Fig 3.

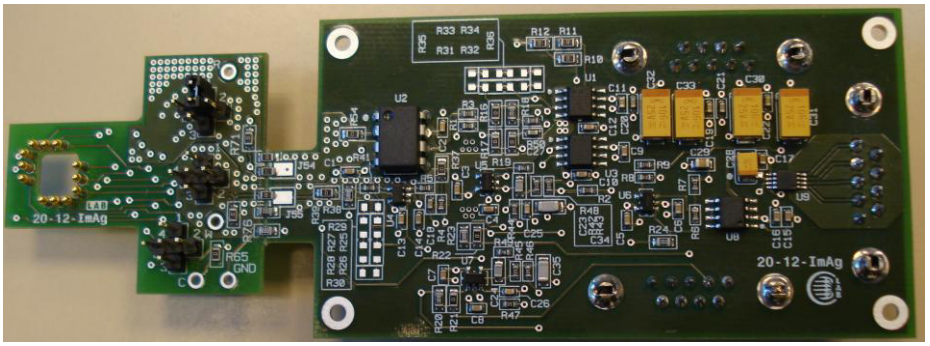


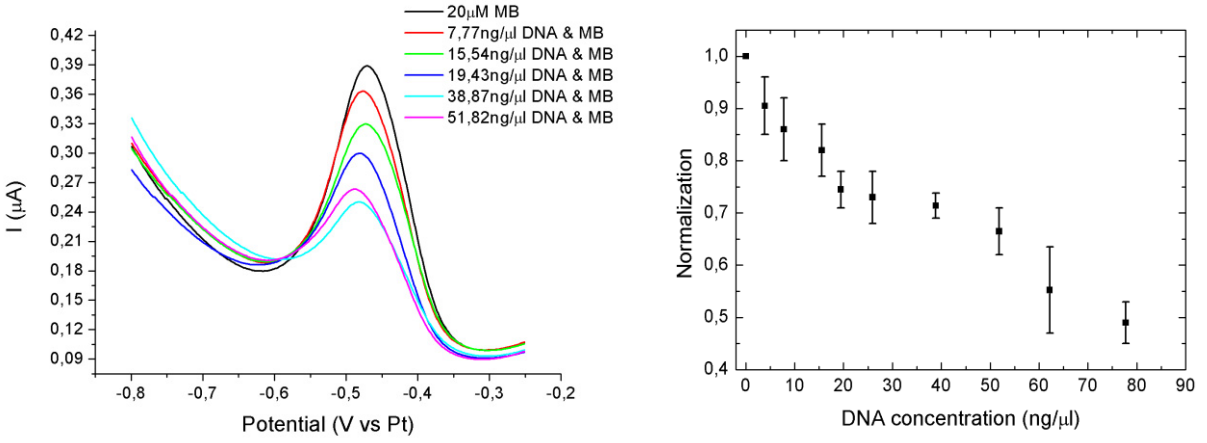
Fig 3. Electronic card.

3. Results and discussion

The developed electrochemical system is tested and compared to a commercial AUTOLAB PGSTAT, obtaining identical results in the performed tests.

The main application of the EDS is to measure different concentrations of DNA. This DNA has been previously amplified in the PCR chamber [3] of the microfluidic cartridge. For the electrochemical detection, square wave voltammetries (SWVs) of solutions of Methylene Blue (MB) with different concentrations of DNA are measured. In Fig 4(a), SWVs of dilutions of PCR products are shown, where the sensor is able to distinguish between different concentrations of DNA. The detection limit of the EDS is of 4ng/µl DNA and taking into account that the measured solutions in the system are previously amplified, this detection limit is lower than the detection limit needed for the LOC device [4].

Finally different tests are made to see the repeatability of the measurement. Fig 4(b) shows the mean values and the obtained highest and lowest currents in measurements carried out in different sensors.



(a) (b)

Fig 4. (a) SWV measurements of solutions of MB with different concentrations of DNA; (b) Deviation curve for different concentrations of DNA.

4. Conclusions

The addition of the described electrochemical detection system to the LOC device, has enabled the fabrication of a low cost, fast response and small dimension device. Although the EDS is not able to make quantitative measurement of DNA, it is able to make qualitative measurements with a detection limit that is enough for the desired application, i.e. for the detection of already amplified DNA.

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